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Constraining the Cosmological Density of Compact Objects with the Long-Term Variability of Quasars E. Zackrisson & N.Bergvall: Constraining Dark Matter with the Long-Term Variability of Quasars E. Zackrisson & N. Bergvall Constraining Dark Matter with the Long-Term Variability of Quasars Erik Zackrisson Nils Bergvall

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By comparing the results from numerical microlensing simulations to the observed long-term variability of quasars, strong upper limits on the cosmological density of compact objects in the 10^{-4} $M_{\odot}$–1 $M_{\odot}$ range may in principle be imposed. Here, this method is generalized from the Einstein-de Sitter universe to the currently favored $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$ cosmology and applied to the latest observational samples. We show that the use of high-redshift quasars from variability-selected samples has the potential to substantially improve current constraints on compact objects in this mass range. We also investigate to what extent the upper limits on such hypothetical dark matter populations are affected by assumptions concerning the size of the optical continuum-emitting region of quasars and the velocity dispersion of compact objects. We find that mainly due to uncertainties in the typical value of the source size, cosmologically significant populations of compact objects cannot safely be ruled out with this method at the present time.Dark matter – gravitational lensing – quasars: general – cosmology: miscellaneous

Introduction Despite much effort to detect or rule out cosmologically significant populations of compact bodies in the stellar to planetary mass range, such objects still remain viable candidates for the dark matter of the universe. Although many of the compact dark matter candidates proposed are baryonic (e.g. red, white and brown dwarfs, neutron stars, stellar black holes, gas clouds) and therefore constrained by standard Big Bang nucleosynthesis and the determination of the primeval deuterium abundance to contribute no more than $\Omega_B h_{100}^2 = 0.02$ (e.g. Burles et al. Burles et al.) to the cosmological density, several candidates do circumvent these constraints, either by being non-baryonic or by making their baryonic content unavailable by the time of nucleosynthesis: e.g. primordial black holes (Hawking Hawking), quark nuggets (Alam et al. Alam et al.), mirror matter MACHOs (Mohapatra Mohapatra) and aggregates of bosons or fermions (Membrado Membrado). A large number of methods do however exist to constrain the cosmological densities of such populations (see Dalcanton et al. Dalcanton et al. and Carr & Sakellariadou Carr Sakellariadou for reviews).

In this paper, we will be concerned with compact objects in the potentially very interesting mass range 10^{-4} $M_{\odot}$–1 $M_{\odot}$, where indirect detections of cosmologically significant populations have been suggested (e.g. Hawkins Hawkins1996). In this region, the currently most powerful constraints on the cosmological density of such objects (regardless of type), $\Omega_{compact}$, come from Dalcanton et al. (Dalcanton et al.) and Schneider (Schneider, hereafter S93), and are both based on theoretically predicted effects of quasar microlensing.

By comparing the equivalent width distribution of quasar emission lines predicted by microlensing scenarios to that of observed samples, Dalcanton concludes $\Omega_{compact} \leq 0.2$ for 10^{-3} $M_{\odot}$–1 $M_{\odot}$ compact objects in a critical universe. Taken at face value, the constraints from S93 are however even stronger at the lowest masses: $\Omega_{compact} \leq 0.1$ for 10^{-3} $M_{\odot}$–$3 \cdot 10^{-2}$ $M_{\odot}$.

The method of S93 is based on the argument that large populations of compact objects should statistically induce variations in quasar light curves larger than those actually observed. The limits derived this way do however rely on the premise that the many parameters going into the microlensing simulations can be sufficiently well constrained by observations or reasonable assumptions, effectively making $\Omega_{compact}$ the only free parameter. The aim of this paper is to investigate whether this may actually be accomplished at the present time. Of particular importance is the ill-determined typical size of the UV–optical continuum-emitting region of quasars, R_{QSO}, which S93 assumes to be $R_{QSO} = 10^{13}$ m when deriving the constraints quoted above.

Here, the method of S93 will be generalized from the Einstein-de Sitter (EdS) universe to the currently favored $\Omega_M = 0.3$, $\Omega_\Lambda = 0.7$ cosmology and applied to the latest observational samples (Hawkins Hawkins2000, hereafter H2000). The sensitivity of the constraints to uncertainties in R_{QSO} and the velocity dispersion of compact objects will be evaluated using recently developed methods to better approximate the magnification in the case of large source microlensing.

Numerical simulations of quasar microlensing Computational method The method used to derive the statistical properties of light curves of quasars microlensed by a cosmological distribution of compact objects is based on the machinery outlined in S93, extended to arbitrary Friedmann-Lemaître cosmologies using the angular size distances of Kayser et al. (Kayser et al.) and to the case of large-source microlensing using the magnification formula of Surpi et al. (Surpi et al.).

In this technique, the multiplicative magnification approximation (Ostriker & Vietri Ostriker Vietri) is assumed to adequately reproduce the statistical probability of variability. In this case, the magnification, μ_{tot}, due to i microlenses is equal to the product of the individual ones: equation $\mu_{tot} = \prod_i \mu_i . eq1$